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MEASURING HAY IN STACKS

LEAFLET No. 72

UNITED STATES
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AGRICULTURE

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MEASURING HAY IN STACKS

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Farmers, ranchers, and hay dealers buy and sell large quantities of hay in the stack. The parties interested in such transactions agree on the quantity of hay in each stack by measuring it and then computing the volume and tonnage by one of several rules in common use.

This method of buying and selling hay is used most extensively in the Western and Great Plains States, where range stock is brought into the valleys in the fall to be wintered on the alfalfa stubble and hay bought from the valley farmers. Occasionally hay dealers buy hay by measure but not as a general practice, for they know that there is likely to be considerable variation in individual stacks and that the tonnage as ascertained by measurement often does not hold out by weight.

Why Hay is Sold by Measure

Hay is sold by measure because in most of the valleys where range stock is wintered there are no scales available to weigh the hay. Even if farm scales were available it would sometimes be impracticable to weigh the hay because of the time and labor required. In most instances the hay is either fed directly from the stack in racks arranged about the stack, or scattered from a wagon or sled about the pasture or feed lot. Loading the hay onto a wagon or sled and hauling it to the scales would often add an expense to the feeding operations that might be as great as or greater than any possible gain from buying the hay by weight instead of by measure.

Hay dealers who purchase hay by measure are usually either operators of alfalfa mills or dealers who plan to resell the hay in the stack. Operators of alfalfa mills often purchase a large part of their yearly hay supply in the late summer or fall, and for this reason they find it advantageous to measure the stacks to ascertain the tonnage in order to settle with the farmer before the hay is delivered to the mill.

Demand for Accurate Method

The United States Department of Agriculture and the State experiment stations receive many inquiries about the rules for determining the volume of hay stacks and the number of cubic feet of hay required for a ton.

The rules in common use for the determination of the volume of both oblong and round stacks were formulated by farmers, stockmen, officers of the United States Army Quartermaster Corps, and others without thorough investigational work. The rules were formulated in order to meet immediate necessities in a practical way.

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In an effort to develop a scientific method the department organized a study of this subject in cooperation with a number of the State agricultural experiment stations. The purpose was to ascertain the accuracy of the rules in use and to develop new rules in case the old rules were found to give inaccurate results. Several thousand oblong and round stacks were measured and weighed in the Western and Great Plains States, and these data were studied and tabulated.

Oblong or Rectangular Stacks

The volume of a rectangular stack is equal to its length multiplied by the area of the cross section. The length can be measured easily, but the exact area of the cross section is not determined so readily because an accurate formula is necessary for computing the area from the two measurements—width and over—that are usually made for this purpose. The width and over measurements are made easily and for this reason those who buy and sell hay by measure use rules that require only three measurements, namely, width, length, and over. Width is the width of the stack at the ground; length is the

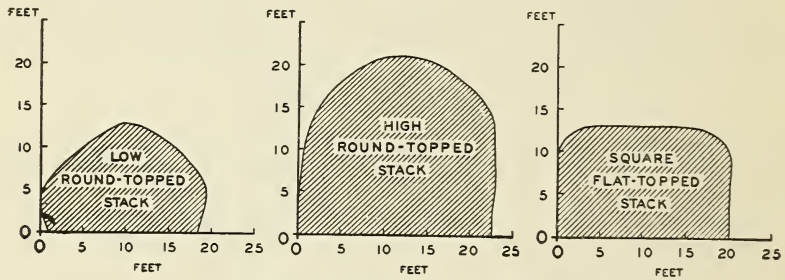

FIGURE 1.—Cross sections of typical oblong stacks

average length of the stack; and over is the distance from the ground on one side over the stack to the ground on the other side.

Former Volume Rules Inaccurate

In the investigations to determine the accuracy of former rules the cross section of each stack was calculated by each of several rules, such as the Frye-Bruhn or rule of two, and the Quartermaster rule, and the results were then compared with the actual cross-section areas of the stacks. This study proved that these rules were not accurate. For certain types and shapes of stacks they gave fairly accurate results, but for other types and shapes the results were very inaccurate.

Cross-section areas determined by the Frye-Bruhn rule averaged only 86 per cent of the actual cross-section areas; the volume of the stacks, therefore, as computed by this rule would be about 14 per cent less than the actual volume. Cross-section areas determined by the Quartermaster rule averaged 96 per cent of the actual cross-section areas, but in some instances this rule gave 25 per cent less and in others 30 per cent more than the actual cross-section area.

New Volume Rules for Oblong Stacks

Investigations were then conducted for the purpose of developing a new rule or rules that would be more nearly accurate and that

would use the same measurements as those used in the old rules. It was found that by dividing hay stacks into three types based on shape, a rule for each type could be developed. The volumes determined by these rules averaged the same as the actual volumes of the stacks, and in no case was the error over 5 per cent.

The three types of stacks (fig. 1), with the rule for each type, are as follows:

For square, flat-topped stacks $(0.56\times O)-(0.55\times W)\times WL$.
For high, round-topped stacks $(0.52\times O)-(0.46\times W)\times WL$.
For low, round-topped stacks $(0.52\times O)-(0.44\times W)\times WL$.

In these rules O equals the over, W equals the width, and L equals the length.

EXAMPLE

To determine the volume of a rectangular stack of the high, round-topped type that is 20 feet wide, 45 feet over, and 50 feet long.

Volume $=(0.52\times 45)-(0.46\times 20)\times(20\times 50)$.

45	20	50
0. 52	0. 46	20
90	9. 20	1, 000
225		
23. 40		
−9. 20		
14. 20		
1, 000		

14, 200. 00 cubic feet in the stack.

These three types of stacks are typical of the oblong stacks built in different parts of the United States. The square, flat-topped stacks are found principally in the Sacramento and San Joaquin Valleys of California; the high, round-topped stacks are common in the intermountain States of Utah, Nevada, and Idaho; and the low, round-topped stacks are the type built in the Great Plains States where the overshot stacker is used.

Round Stacks

Studies of the data obtained regarding round stacks also showed that the rules in common use for determining the volume of round stacks are inaccurate. Volume of round stacks determined by the Quartermaster rule or so-called Government rule averaged 95 per cent of the actual volume, although in some individual cases the volume obtained by this rule gave results that were more than 20 per cent from the actual volume. A simple rule or formula, similar to the ones given for oblong stacks, could not be developed, but Table 1 gives the volume of round stacks when the circumference is between 45 and 98 feet and the over between 25 and 50 feet. The volume of stacks having circumferences or overs greater or less than those given in Table 1 can be calculated by using the formula: Volume $=(0.04\times O)-(0.012\times C)C^2$. In this formula C equals the circumference or distance around the

stack at the ground and O equals the over or distance from the ground on one side over the peak to the ground on the other side. Usually it is advisable to take two over measurements at right angles to each other, and to average them.

EXAMPLE

To determine the volume of a round stack that is 100 feet in circumference and has an average over of 60 feet.

Volume $= (0.04 \times 60) - (0.012 \times 100) \times (100)^2$.

60	100	100
0. 04	0. 012	100
2. 40	200	10, 000
−1. 20	100	
1. 20	1. 200	
10, 000		

12, 000. 00 cubic feet in the round stack.

Volumes given in the table or determined from the formula will, on the average, amount to the actual volume of the stacks and in most individual cases the volume will not vary more than 10 per cent from the actual volume.

Cubic Feet Per Ton

Many factors affect the density of hay in the stack and therefore the number of cubic feet required for a ton of hay. The factor that causes the greatest variation is probably moisture in the hay at stacking time. Tough or slightly undercured hay will settle and become more compact than very dry or overcured hay. Other factors like texture and foreign material may affect the density also, but probably not to the same extent as moisture. For these reasons there is often a considerable difference in the number of cubic feet required for a ton in different stacks, and, at present, there are no simple methods for measuring variations in density.

The following figures, which are the averages obtained from a large number of stacks, can be used with fairly good results:

Kind of hay	Length of time in stack	
	30 to 90 days	Over 90 days
Alfalfa	485 cubic feet per ton	470 cubic feet per ton.
Timothy and timothy mixed	640 cubic feet per ton	625 cubic feet per ton.
Wild	600 cubic feet per ton	450 cubic feet per ton.

When these figures are used with the rules for determining volume herein recommended more accurate results will be obtained than if such rules as the Frye-Bruhn or Quartermaster rules are used with such figures for cubic feet per ton as have been in common use heretofore.

TABLE 1.—*Volume of round stacks of hay of specified dimensions*

[Volume figures given to the nearest 5]

Circumference (feet)	Indicated volume in cubic feet when the over is—												
	25 feet	26 feet	27 feet	28 feet	29 feet	30 feet	31 feet	32 feet	33 feet	34 feet	35 feet	36 feet	37 feet
45	825	960	1,090										
46	840	975	1,105	1,235									
47	855	990	1,120	1,250	1,385	1,505							
48	870	1,005	1,135	1,265	1,400	1,525	1,650	1,785					
49	885	1,020	1,150	1,285	1,420	1,540	1,670	1,805	1,935				
50	900	1,035	1,165	1,300	1,435	1,560	1,690	1,825	1,955	2,090	2,215		
51	915	1,050	1,180	1,315	1,450	1,580	1,710	1,845	1,980	2,110	2,240	2,370	2,495
52	930	1,065	1,200	1,330	1,465	1,600	1,730	1,865	2,000	2,130	2,265	2,400	2,530
53	945	1,080	1,215	1,345	1,485	1,615	1,750	1,880	2,020	2,155	2,290	2,430	2,560
54	960	1,095	1,230	1,360	1,500	1,630	1,770	1,900	2,040	2,180	2,320	2,460	2,595
55	975	1,110	1,245	1,380	1,515	1,650	1,790	1,920	2,065	2,205	2,345	2,490	2,630
56	990	1,125	1,260	1,395	1,530	1,665	1,810	1,940	2,085	2,230	2,375	2,520	2,660
57	1,005	1,140	1,275	1,410	1,550	1,685	1,830	1,960	2,105	2,250	2,400	2,545	2,695
58	1,020	1,155	1,290	1,435	1,565	1,705	1,850	1,980	2,125	2,275	2,425	2,575	2,725
59	1,035	1,170	1,310	1,450	1,580	1,720	1,865	2,000	2,150	2,300	2,455	2,605	2,755
60	1,050	1,185	1,325	1,465	1,600	1,740	1,885	2,020	2,170	2,325	2,480	2,635	2,790
61	1,065	1,200	1,340	1,485	1,615	1,760	1,905	2,040	2,195	2,345	2,510	2,665	2,825
62	1,080	1,215	1,355	1,500	1,635	1,775	1,925	2,060	2,215	2,365	2,535	2,695	2,855
63	1,095	1,230	1,370	1,515	1,655	1,795	1,945	2,080	2,235	2,390	2,560	2,725	2,890
64	1,110	1,245	1,385	1,530	1,670	1,810	1,960	2,100	2,260	2,415	2,585	2,755	2,920
65	1,125	1,260	1,400	1,545	1,685	1,830	1,980	2,120	2,280	2,440	2,615	2,780	2,950
66	1,140	1,275	1,420	1,560	1,705	1,850	2,000	2,140	2,300	2,465	2,640	2,810	2,985
67	1,155	1,290	1,435	1,575	1,720	1,865	2,020	2,160	2,325	2,485	2,665	2,840	3,015
68	1,170	1,305	1,450	1,595	1,740	1,885	2,040	2,180	2,345	2,510	2,690	2,870	3,050
69	1,185	1,320	1,465	1,610	1,755	1,905	2,055	2,200	2,365	2,530	2,715	2,900	3,080
70	1,200	1,335	1,480	1,625	1,770	1,925	2,075	2,220	2,385	2,555	2,745	2,930	3,115
71	1,215	1,350	1,495	1,640	1,790	1,940	2,095	2,240	2,405	2,580	2,770	2,960	3,145
72	1,230	1,365	1,515	1,660	1,805	1,960	2,115	2,260	2,430	2,605	2,795	2,990	3,175
73	1,245	1,380	1,530	1,675	1,820	1,975	2,135	2,280	2,450	2,625	2,825	3,015	3,210
74	1,260	1,395	1,545	1,690	1,840	1,995	2,150	2,300	2,470	2,650	2,850	3,045	3,245
75		1,410	1,560	1,705	1,855	2,010	2,170	2,320	2,495	2,675	2,875	3,075	3,275
76		1,425	1,575	1,725	1,870	2,030	2,190	2,340	2,515	2,695	2,905	3,105	3,310
77			1,590	1,740	1,890	2,050	2,210	2,360	2,540	2,720	2,930	3,135	3,340
78			1,605	1,755	1,905	2,070	2,230	2,380	2,560	2,745	2,955	3,165	3,375
79				1,775	1,925	2,090	2,250	2,400	2,580	2,765	2,980	3,195	3,405
80				1,790	1,945	2,105	2,270	2,420	2,605	2,790	3,010	3,225	3,440
81				1,805	1,960	2,125	2,285	2,440	2,625	2,815	3,035	3,255	3,470
82				1,820	1,975	2,145	2,305	2,460	2,645	2,835	3,060	3,280	3,500
83					1,995	2,160	2,325	2,480	2,665	2,860	3,090	3,310	3,535
84						2,180	2,345	2,500	2,690	2,880	3,115	3,340	3,570
85								2,520	2,710	2,905	3,140	3,370	3,600
86									2,735	2,930	3,170	3,400	3,635
87											3,195	3,430	3,665
88												3,460	3,700
89												3,490	3,730
90													3,765
91													
92													
93													
94													
95													
96													
97													
98													

TABLE 1.—*Volume of round stacks of hay of specified dimensions*—Continued

[Volume figures given to the nearest 5]

Circumference (feet)	Indicated volume in cubic feet when the over is—												
	38 feet	39 feet	40 feet	41 feet	42 feet	43 feet	44 feet	45 feet	46 feet	47 feet	48 feet	49 feet	50 feet
45													
46													
47													
48													
49													
50													
51													
52	2,665	2,795											
53	2,700	2,835	2,975										
54	2,735	2,875	3,015	3,160									
55	2,770	2,915	3,060	3,210	3,360	3,505							
56	2,805	2,955	3,105	3,255	3,415	3,565	3,720						
57	2,845	2,995	3,150	3,305	3,465	3,625	3,785	3,940					
58	2,880	3,035	3,195	3,350	3,515	3,680	3,850	4,010	4,175				
59	2,915	3,075	3,235	3,400	3,570	3,740	3,915	4,080	4,245	4,415			
60	2,950	3,115	3,280	3,445	3,625	3,795	3,975	4,150	4,320	4,490	4,670		
61	2,985	3,155	3,325	3,495	3,675	3,855	4,040	4,215	4,390	4,570	4,750	4,925	
62	3,020	3,195	3,365	3,540	3,730	3,915	4,105	4,285	4,465	4,650	4,830	5,015	5,200
63	3,055	3,235	3,410	3,585	3,780	3,970	4,165	4,355	4,540	4,730	4,910	5,105	5,295
64	3,090	3,275	3,455	3,635	3,835	4,030	4,230	4,425	4,615	4,805	4,995	5,195	5,390
65	3,125	3,315	3,495	3,680	3,885	4,085	4,290	4,490	4,690	4,885	5,075	5,285	5,485
66	3,160	3,355	3,540	3,730	3,935	4,145	4,355	4,560	4,760	4,960	5,160	5,370	5,580
67	3,195	3,395	3,585	3,780	3,990	4,205	4,420	4,630	4,830	5,040	5,245	5,460	5,670
68	3,230	3,430	3,630	3,825	4,045	4,265	4,485	4,695	4,900	5,120	5,330	5,550	5,765
69	3,265	3,470	3,670	3,875	4,095	4,320	4,545	4,760	4,970	5,195	5,415	5,640	5,860
70	3,300	3,510	3,715	3,920	4,150	4,375	4,610	4,825	5,045	5,275	5,495	5,730	5,955
71	3,335	3,550	3,760	3,970	4,205	4,435	4,670	4,895	5,120	5,355	5,580	5,820	6,050
72	3,375	3,590	3,805	4,015	4,255	4,495	4,735	4,965	5,195	5,435	5,665	5,910	6,145
73	3,410	3,630	3,845	4,065	4,310	4,550	4,795	5,030	5,270	5,515	5,750	6,000	6,240
74	3,445	3,665	3,890	4,110	4,360	4,610	4,855	5,095	5,340	5,595	5,835	6,090	6,335
75	3,480	3,705	3,935	4,160	4,415	4,670	4,915	5,165	5,415	5,675	5,915	6,180	6,430
76	3,515	3,745	3,975	4,205	4,465	4,725	4,980	5,235	5,490	5,750	6,000	6,270	6,525
77	3,550	3,785	4,020	4,250	4,520	4,785	5,045	5,305	5,560	5,830	6,085	6,355	6,620
78	3,585	3,825	4,065	4,300	4,570	4,840	5,105	5,370	5,635	5,910	6,170	6,445	6,715
79	3,620	3,865	4,105	4,345	4,625	4,895	5,170	5,440	5,710	5,990	6,255	6,535	6,810
80	3,655	3,905	4,150	4,395	4,675	4,955	5,235	5,510	5,785	6,070	6,340	6,625	6,905
81	3,690	3,945	4,195	4,440	4,730	5,010	5,295	5,575	5,855	6,145	6,425	6,715	7,000
82	3,725	3,985	4,240	4,490	4,785	5,070	5,360	5,645	5,930	6,225	6,510	6,800	7,090
83	3,760	4,025	4,280	4,535	4,830	5,130	5,425	5,715	6,005	6,305	6,595	6,890	7,185
84	3,795	4,065	4,325	4,580	4,885	5,190	5,485	5,785	6,080	6,385	6,675	6,980	7,280
85	3,830	4,105	4,365	4,630	4,935	5,245	5,550	5,850	6,155	6,465	6,760	7,070	7,375
86	3,865	4,145	4,410	4,675	4,990	5,300	5,615	5,920	6,230	6,545	6,845	7,160	7,470
87	3,900	4,185	4,455	4,725	5,040	5,360	5,680	5,990	6,300	6,620	6,930	7,250	7,565
88	3,940	4,220	4,500	4,770	5,090	5,420	5,745	6,060	6,375	6,700	7,015	7,340	7,660
89	3,975	4,260	4,540	4,815	5,145	5,475	5,805	6,125	6,450	6,780	7,100	7,430	7,755
90	4,010	4,300	4,585	4,860	5,200	5,535	5,865	6,195	6,525	6,860	7,185	7,520	7,845
91	4,045	4,340	4,630	4,910	5,250	5,595	5,930	6,265	6,600	6,940	7,270	7,605	7,940
92	4,080	4,380	4,670	4,955	5,305	5,650	5,995	6,335	6,675	7,020	7,355	7,695	8,035
93		4,420	4,715	5,005	5,360	5,710	6,055	6,400	6,750	7,095	7,440	7,785	8,130
94		4,460	4,760	5,050	5,410	5,765	6,120	6,470	6,825	7,175	7,525	7,875	8,225
95			4,805	5,100	5,465	5,825	6,180	6,540	6,895	7,255	7,610	7,965	8,320
96				5,150	5,515	5,885	6,245	6,610	6,970	7,335	7,695	8,055	8,415
97				5,195	5,570	5,945	6,310	6,680	7,045	7,415	7,780	8,145	8,510
98					5,625	6,000	6,370	6,750	7,120	7,495	7,865	8,235	8,605

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